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Dynamics of *Aedes aegypti* Distribution and Density

Seasonal Fluctuations in the Americas

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By distribution of *Aedes aegypti*, one means its geographical range. Density is more difficult to determine; it is inadequately measured by the *A. aegypti* index (that is, the percentage of houses with evidence of the breeding of *A. aegypti*). Density is affected not only by the number and distribution of infested houses, but also by the number and size of available breeding-places. Both distribution and density are affected by rainfall and temperature; seasonal fluctuations may be very great.

MECHANISM OF SPREAD OF *A. AEGYPTI*

A. aegypti, originally a tree-hole breeder in Africa, owes its world-wide distribution to its adaptation to human habitation, to breeding in artificial water containers, and to travelling with man. Of special importance is the longevity of its eggs.

The sailing ships of the fifteenth to nineteenth centuries, with their open water containers, were extremely favourable for the distribution of *A. aegypti* by sea. It is probable that practically all of the seaports of the tropical and temperate zones of the world have been visited repeatedly by *A. aegypti*.

River boats throughout the world are generally favourable to the breeding and transportation of *A. aegypti*. In the tropics and subtropics, the principal river valleys have all been infested, at least up to the first waterfall.

Steam-operated railways have played their part in the distribution of *A. aegypti* away from the seacoasts and river ports. At times, the breeding of *A. aegypti* has been found only in and about the railway stations at interior points.

In its aquatic forms, *A. aegypti* may travel with man in whatever conveyance he may use; it may even travel with him on foot. Religious pilgrims in the semi-arid regions of north-east Brazil carry drinking water in small clay pots; these pots have disseminated *A. aegypti* widely through the rural areas of several States of that country.

The adult *A. aegypti* has been observed travelling by passenger automobile in Brazil and has been collected from automobiles crossing the Venezuelan-Colombian border. It travels freely in passenger coaches on trains and was repeatedly found in aircraft arriving in Brazil from Africa in the pre-DDT period.

In summary, *A. aegypti* may travel with man as adult, larva or egg under almost any conditions. On the other hand, *A. aegypti* is rarely found on the large, modern, ocean-going steamship. Also, there are considerable areas in the interior of South America, suitable for *A. aegypti* breeding, where it has never penetrated. In the Amazon Valley, *A. aegypti* was generally found in the cities and towns below the first waterfall in each tributary, but in many cases it had failed to get around the portage.

In certain instances, local folklore establishes the approximate date of the arrival of *A. aegypti* in important cities in the interior and suggests the mechanism of importation. When yellow fever appeared in Santa Cruz de la Sierra, Bolivia, in 1932, the people declared that *A. aegypti* was a newcomer to their town about 1919. They associated its appearance with the installation of electrical power for the city; they believed the electric lights had attracted this mosquito into the town. In retrospect, it seems probable that the equipment for the power plant became infested with eggs and aquatic forms of *A. aegypti* on its long trip to Santa Cruz through the Amazon Valley.

Similarly, in Bucaramanga, Colombia, the old inhabitants insisted that *A. aegypti* had been unknown in their youth. This mosquito had suddenly appeared, however, about 1908 or 1909, many years before the construction of the railroad, as a new pest in the city. The people, noting a resemblance between this new mosquito and the figure of their archbishop, who visited Bucaramanga about that time, named the mosquito for him. The archbishop

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had come to dedicate a religious statue recently imported from Italy. Probably this statue offered a suitable breeding-place for *A. aegypti* as it was transported up the Magdalena River from Barranquilla.

A. aegypti does not tend to fly for long distances in search of breeding-places; expansion of an infested area therefore occurs slowly, except where transportation with man is a factor.

RANGE OF *A. AEGYPTI* IN THE AMERICAS

Early history

The date of arrival of *A. aegypti* in the Western Hemisphere is unknown; it may even have come with Columbus or some of his early followers.

That it did arrive fairly early is indicated by records of outbreaks of yellow fever in the sixteenth century.

There was a time when ports along the northern Atlantic seabord of the USA, and even of Canada, suffered summer epidemics of yellow fever. These outbreaks must have depended on spring or early summer importation of *A. aegypti* by boat from the West Indies and later introduction of yellow-fever virus. As late as 1878, a widespread epidemic of yellow fever occurred in the Mississippi Valley. For many decades, the traditional home of yellow fever was in the ports of the Caribbean Sea and the Gulf of Mexico, with extension to the Pacific coast of South America.

A great deal is known about the distribution of *A. aegypti* in the yellow-fever areas following the demonstration in 1901 that yellow fever can be controlled—can be prevented—by an attack on this mosquito. Following the success of numerous local campaigns, the Rockefeller Foundation undertook the eradication of yellow fever, beginning in 1915. As a result, considerable information on the distribution of *A. aegypti* became available in certain Latin American countries. This information has been greatly extended and completed since 1930, with the attack directed against the *A. aegypti* mosquito itself rather than against yellow fever. Species eradication requires complete survey and coverage of its entire range.

Period since 1930

In 1930, when the reorganization of the yellow-fever operations which led to the programme for the eradication of *A. aegypti* began, this mosquito ranged in the Americas from Oklahoma and Tennessee in the USA to Buenos Aires in Argentina and Tocopila in Chile; it occurred in all countries, territories and islands within this range. Eradication of *A. aegypti* in the Western Hemisphere therefore requires the active participation of all of the countries and territories situated there, except for Canada and the Falkland Islands.

Within its range, *A. aegypti* was not uniformly distributed, even where temperature and humidity were favourable. Several tributaries to the Amazon were not infested above the first waterfall, and even below this barrier *A. aegypti* was often found only in the larger cities and towns. Isolated homesteads and villages were free of *A. aegypti*; this freedom was apparently due to easy access to river water and lack of need for storage of water for domestic needs.

Throughout its range, *A. aegypti* was generally a domestic mosquito of cities, towns and villages, but three areas of serious rural infestation were found. These were in the semi-arid States of north-east Brazil, in the delta of the Magdalena River in Colombia, and in the Yucatan Peninsula of Mexico. In these areas, the prolonged dry season leads to extensive storage of domestic water reserves.

A. aegypti breeding was generally limited to human artefacts, but bamboo stems, coconut shells, fallen leaves and damaged papaya trees proved to be dangerous. Tree-holes along city streets and parks were sometimes infested, but tree-hole breeding was never found in the forests away from human habitation. In the Americas, *A. aegypti* does not breed in rain pools on the ground.

There is apparently perfect adaptation of *A. aegypti* to the old automobile tire, whether it is abandoned or is being collected and shipped for recapping, for the making of sandals, or for ships' bumpers.

Present distribution (1965)

The present known distribution of *A. aegypti* is limited to the northern fringe of South America, to the islands of the West Indies, and to the USA. (Reinfestation in San Salvador, the capital of El Salvador, is reported as of July 1965.) The following countries on the mainland of the Americas have been freed of *A. aegypti*: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, British Honduras, Guyana, French Guiana, El Salvador, Mexico, Nicaragua, Panama, Paraguay, Peru and Uruguay. (Guyana and French Guiana have been reinfested since 1963.) On the

mainland of the Americas, Venezuela, the USA and the three Guianas are still infested. Cuba, Haiti, Jamaica, Puerto Rico, the Dominican Republic, Trinidad, and the smaller islands of the Caribbean must be cleared before the threat of reinfestation will be over.

SOURCE OF REINFESTATION

Since the eradication effort began in the 1930s, a great deal of work has been done on the epidemiology of *A. aegypti* reinfestation. This has been attributed to direct flight of *A. aegypti* only in closely contiguous areas. Trains, automobiles, and coastal and river boats have been incriminated. The transportation of an infested water container with the effects of a family moving from one place to another has been found guilty. Old tires moved by railroad, by truck and by boat have been held responsible.

So far as is known, no country in the Americas has been reinfested from other regions of the world since the eradication effort started.

The only long-distance movement of *A. aegypti* held responsible for a reinfestation has been the apparent movement in old automobile tires from the USA to El Salvador in 1965.

Experience has shown that eradication can be accomplished within a country with a limited staff working progressively from one section to another, using minimal resources to prevent reinfestation of cleared areas.

Seasonal fluctuations

Seasonal fluctuations of the range of *A. aegypti* do occur at the periphery of its geographical and altitudinal range; exceptionally cold winters may temporarily reduce the infested area to an appreciable degree.

Both the breeding index and the density of *A. aegypti* are affected by temperature and rainfall. In tropical areas, the effect of rainfall alone is quite apparent. In temperate areas, *A. aegypti* may practically disappear during the winter months and slowly increase in density during the spring and early summer. Traditionally, the transmission peak for yellow fever is early autumn.

Drought does not necessarily reduce the range of *A. aegypti* but may reduce its density. The obligatory storage of water during drought periods helps preserve the *A. aegypti* mosquitos in such areas.

Seasonal fluctuations in *A. aegypti* distribution and density, important as they are to the health officer concerned with epidemic control, lose their importance when the objective is the eradication of *A. aegypti* rather than temporary disease prevention.